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SYSTEMATIC PLANNING METHOD OF DISRUPTION OF RUBBLE PILE ASTEROIDS BY NATURAL VIBRATION MODE ANALYSIS

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ABSTRACT

This study introduces a systematic planning method of disruption of rubble pile asteroids by natural vibration mode analysis, which is based on Discrete Element Method (DEM). DEM is one of the popular methods to simulate dynamic behavior of grains or particles (e.g. impact of rubble pile asteroids, crater formation, dust aggregation). It reflects on a lot of physical parameters of particles such as size, density, and stiffness, and is a useful way to understand dynamics of rubble pile asteroids.

By modelling a rubble pile asteroid as a group of particles that are bound with each other by gravitational force, stress distribution in a static state is calculated by DEM. A mass matrix is calculated from the physical properties of the particles and a stiffness matrix is calculated from the stress distribution according to formulas derived in this study, and natural vibration modes and natural frequencies are finally obtained. Natural vibration modes are usually used for linear vibration analysis, but it is also applicable to analysis of initial response to impact, where influence of nonlinearity of the dynamics is relatively small. In other words, disruption motion of a rubble pile asteroid in a short period of time after impact is approximately expressed by a series of its natural vibration modes.

Evaluation of disruption by natural vibration modes helps construct a strategy of artificial impact. When considering an impact mission, estimation of disruption motion by simulation is required in advance. With a given model of a target asteroid and the conventional DEM, many sets of numerical simulation with various initial condition to search for a desired and required result is an only way for the estimation, and it takes a long time to compute the numerical integration. On the other hand, with its natural vibration modes, it is systematically derived because the motion is simply expressed with their liner sum and the initial condition to realize the required state can be easily solved conversely. For example, an optimal impact point and optimal impact direction to maximize peak strain energy in an arbitrary area can be approximately solved by the proposed method. It is useful to obtain the first estimation to construct the impact scenario.

This study shows its applicability to planning of impact with demonstration of calculation examples. It is shown that the newly proposed method is helpful for understanding disruption of rubble pile asteroids and construction of impact scenario.

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